THE ANSEL DUNHAM LECTURE

A ONCE AND FUTURE EXTRACTIVE HISTORY OF BRITAIN

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Abstract

Geology, geography and human affairs have combined to give Britain a rich history of mineral extraction which stretches back several thousand years. Changing technological, economic and social factors means that the character and scale of domestic extraction have varied enormously over this time span. These same factors have also influenced our level of trade in minerals and metals with the rest of the world. Cornish tin established Britain as a supplier of metal across the ancient world. Norman masons utilised huge quantities of dimension stone to build cathedrals and castles. Wooden ships sheathed with copper from south west England, Wales and the Lakes secured a global empire for Britain in the 17th and 18th Century. Indigenous coal and iron were the basis of Victorian and Edwardian prosperity. Aggregates for road building literally formed the foundation of the post-war 'great car economy'.

Economic globalisation, technology shift and changes in societal attitudes in the late 20th and early 21st Century caused a precipitous decline in domestic output of some minerals, notably metals and coal. The British seemed content to let the global market provide their material needs and happy to export the impacts of mineral extraction to other countries. However, by 2050 it is likely that human population will be close to 9 billion, economic power will have shifted from the West, environmental change will be accelerating and global competition for resources will be intense. In the face of this enormous challenge, will indigenous minerals make a comeback and increase their contribution to our security and prosperity?

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Introduction

Britain has a long history of mineral extraction stretching back over four thousand years. The variety and spatial distribution of domestic minerals has had a major influence on our economic and social development, as well as our landscape and environment. A long and complex geological history has combined with locational factors to give a rich heritage of mineral extraction, although the scale and variety of domestic minerals output declined substantially in the 20th Century. The factors behind this decline are powerful, pervasive and complex. However, as human population grows and global economic power shifts, high commodity prices, changing technology and renewed concerns about supply security are driving new interest in minerals extraction in Britain.

Geology, Geography And Historic Mineral Extraction In Britain

For a relatively small country, Britain has a long and complex geological history, including several episodes of crustal collision and extension, as well as extremes of climate from polar to tropical. This has given rise to a very diverse range of mineral resources in a wide range of settings. The compact and complex nature of British geology sometimes means that different resources are conveniently co-located. For example, the juxtaposition of coal, iron ore and fireclay in late Carboniferous sediments overlying early Carboniferous or Silurian limestones presented 18th and 19th Century industrialists with all the major raw materials for iron-making within relatively small areas of the West Midlands, South Wales and central Scotland.

Although the fact that Britain is an island may be obvious, the extent to which this has (from pre-historic times) facilitated relatively easy waterborne trade in minerals and metals within the British Isles, with Europe and then latterly with the rest of the world is less well known. The growth in canals and railways during the industrial revolution was largely a result of the need to link mineral extraction and processing (supply) with centres of construction, manufacture, consumption and export (demand).

Despite the fact that domestically produced minerals have had a major influence on economic and human development in Britain, the impact of the extraction, processing and trade of many of these minerals is now largely forgotten.

Cornish tin: A critical metal in the Ancient World

Bronze containing between 5 and 20 per cent tin was developed in the Middle East around 3500 BC. This new technology spread rapidly through the Ancient World and by 2000 BC, alluvial tin was being extracted in Cornwall, driven by demand from burgeoning Bronze-Age civilisations in the Mediterranean (Gerrard, 2000). Phoenicians, Greeks and Romans all traded with the 'Cassiterides' ('Tin Islands') on the north western edge of the known world. Some archaeological evidence suggests that the trade was partly controlled by Celtic tribes based in what is now Brittany (Penhallurick, 1986).

Dimension stone in Mediaeval England

The need for elites in Mediaeval England to defend themselves, project power and ensure entry into the Kingdom of Heaven drove them to construct castles, churches and monasteries. This resulted in the development of a thriving industry in the extraction, transport and processing of vast amounts of high quality dimension stone (Purcell, 1967). For example, 14th Century masons used Jurassic limestone from Ancaster in Lincolnshire to build churches and priories in Norwich. Large quantities of stone were transported over 200km by barge, ship and 'creaking carts on wretched roads' (Alexander, 1995).

British copper and the rise of Empire

The beginnings of the industrial revolution in the 18th Century coincided with Britain's rise as a global maritime power. This imperial expansion was literally underpinned by copper mined in Wales, south west England or the Lake District and most likely smelted in Swansea. Copper sheathing protected Royal Navy ships from fouling, making them faster, more manoeuvrable and able to stay at sea longer than those from rival powers (Lavery, 1987). Fourteen tonnes of copper was required to sheath a 74-gun warship.

Midlands iron ore and the defence of the Realm

Following the invention of a process to remove phosphorous from iron in 1875 by Thomas Gilchrist, the iron and steel industry in England started to utilise ore from Jurassic and Cretaceous sedimentary rocks in the Midlands. Underground and open pit mining was carried out on a large scale and 'ironstone' extraction was a major industry in otherwise rural counties such as Northamptonshire, Leicestershire and Lincolnshire (Figure 1; Tonks, 1988). This secure, domestically-produced source of iron ore was strategically important during the First and Second World Wars when imports from abroad were restricted. Global economic conditions and technological change in metallurgical manufacturing signalled the demise of the high phosphorous domestic Mesozoic iron ores in the 1970s.

Ascent, Decline And Fall Of Domestic Minerals Extraction

The Industrial Revolution in the 18th and 19th Century was the driving force behind the rapid growth in output from the British extractive sector at this time. By the mid 19th Century, Britain was a minerals superpower producing nearly 50 per cent of global copper output (British Geological Survey, 2012). At the beginning of the 20th Century, mined coal output from Britain was almost 300 million tonnes per annum (British Geological Survey, 2012). Demand for domestic minerals was driven by rapid population growth and the growth in a middle class with more consumer spending power in both Britain and her colonies. This instigated rapid expansion in construction and manufacturing, much of it powered by steam raised by burning coal. As well as creating demand for metals and minerals, technological change also improved supply by expanding the resource base. Steam-power allowed access to resources such coal and base metals through de-watering. New metallurgical processing technologies allowed different and lower-grade ore types to be utilised.

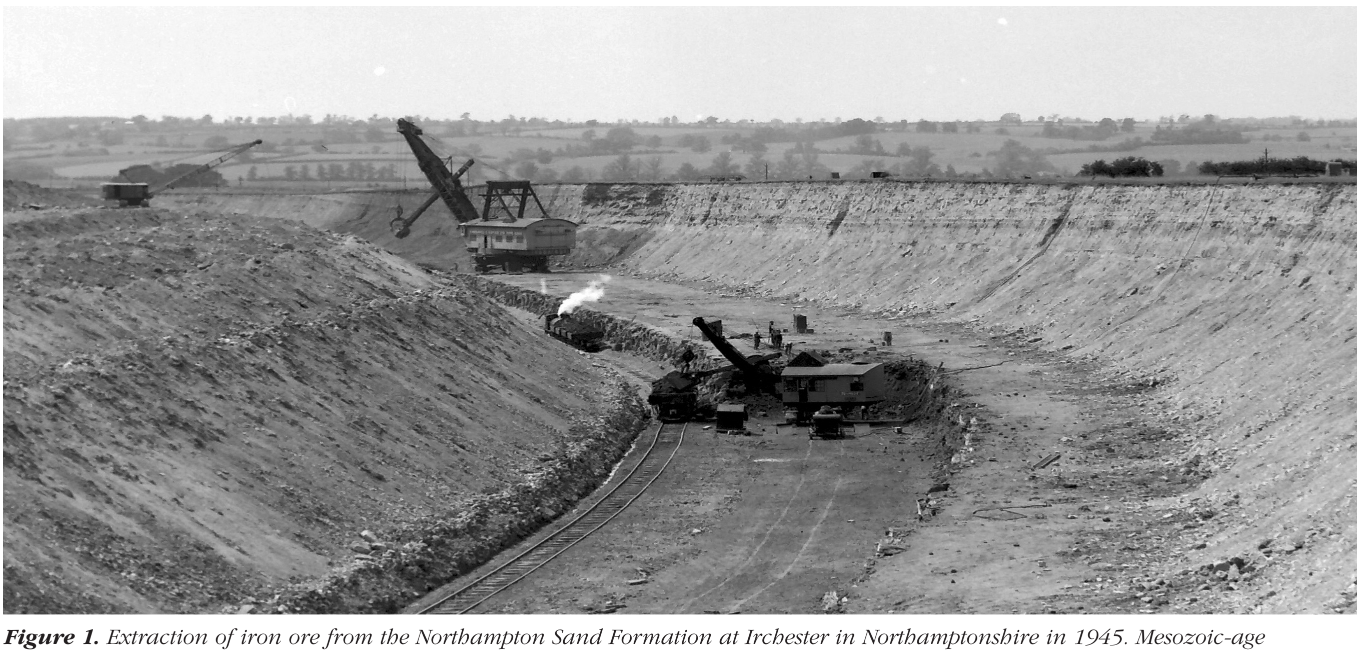

Figure 1. *Extraction of iron ore from the Northampton Sand Formation at Irchester in Northamptonshire in 1945. Mesozoic-age sedimentary iron ores were a vital and secure resource during two World Wars. Image © NERC.*

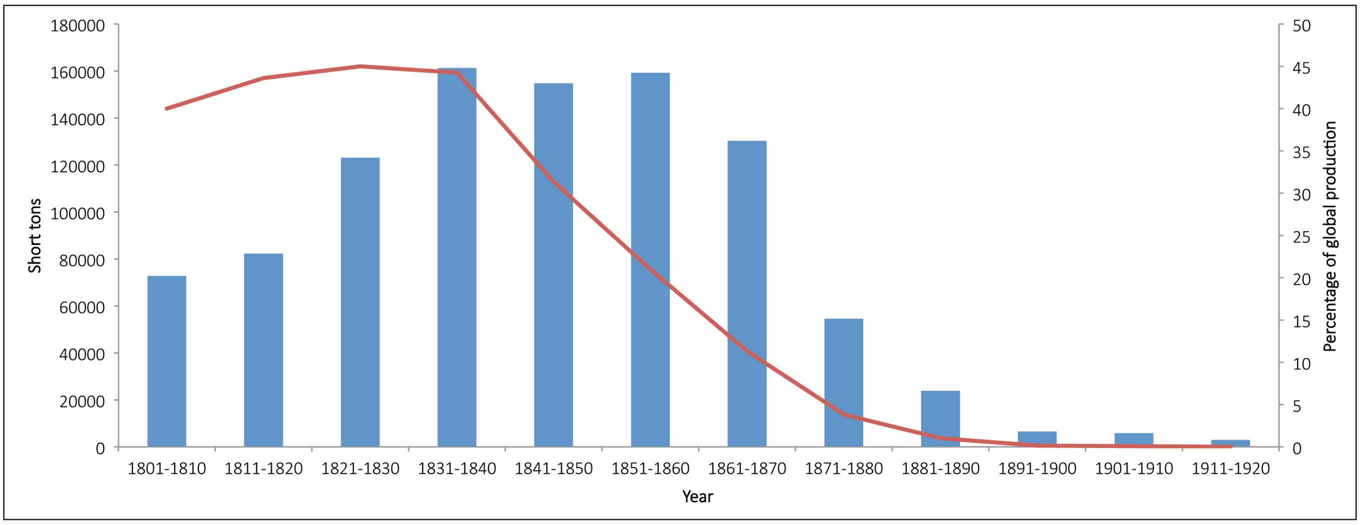

Figure 2. *UK copper production 1800 to 1920 (Data from US Bureau of Mines). (The red line shows the percentage of global production and the blue, vertical bars the production in short tons).*

Domestic output of copper declined rapidly from its peak in the mid-19th Century (Figure 2). This was followed by declining domestic production of coal and iron ore in the 20th Century. Construction aggregates output peaked in the 1980s, oil and gas around 2000 (BGS, 2012). The reasons for the decline of domestic output from Britain are complex and apply in different ways to different minerals although there are some generic factors which are worthy of further examination.

Technological change

The scientific and technological progress which drove demand for domestic minerals and improved access to their supply in the 18th and 19th Centuries did not stop its relentless development. Advances in extraction technology, along with better understanding of ore deposit geology, allowed the development of larger, lower grade, lower cost deposits elsewhere in the world. The scale and reliability of global logistics improved, facilitating long distance, low cost transport of minerals from mine to market. These economies of scale and other factors rendered many domestic minerals operations economically unviable. Technological change has also impacted on demand. Oil and gas have to a large extent replaced coal as a primary source of energy. Heavy industries which consume large quantities of minerals also benefit from economies of scale and have also, to some extent, moved away from Britain to places where it is easier and cheaper to operate.

Social attitudes

In the latter part of the 20th and the early 21st Century, these technological and economic pressures on domestic mineral extraction were joined by a series of social and environmental factors that have further accelerated this decline. British public attitudes have become overwhelmingly hostile to domestic mineral extraction. A woeful historic record of environmental impact, together with high population density, social change and a rise in environmental 'consciousness' has resulted in a domestic minerals sector routinely confronted by communities and individuals engaged in place protective action (sometimes labelled 'nimbyism'). Paradoxically, this challenging situation is underlain by a post-Cold War 'market will provide' globalisation paradigm which tends to conceal the true impact of conspicuous consumption.

Structural changes in the British economy mean that many individuals are unaware of the link between raw materials and the technology which we now require to maintain our lifestyle. In 1981, 5.7 million people worked in the manufacturing sector, in 2011, this figure had fallen to just 2.5 million (Maer and Rhodes, 2013). Increased per capita wealth in Britain raised the level of house ownership from 57 per cent in 1981 to 71 per cent in 2003 (Nationwide Building Society, 2013). This increase in property ownership and (and real house prices) is likely to increase sensitivity toward mineral development. These socio-economic factors have been accompanied by increasing public concern regarding the environment. The British environmental movement was begun by mid-Victorian intellectuals such as John Ruskin and William Morris and was established in the late 19th Century by the founding of the Royal Society for the Protection of Birds (RSPB) in 1889 and the National Trust (NT) in 1895. In 2010, RSPB membership was about 1 million and the NT was about 3.5 million (McGuiness, 2012). This compares to a combined membership of about 400,000 for all major GB political parties in the same year (McGuiness, 2012). High population density, combined with relatively high standards of living mean that the British public value their environment, both in their immediate area and in the form of protected landscapes and habitats further afield. This level of sensitivity resonates very strongly with those who set policy regarding licence to operate a mineral extraction operation (Bloodworth et al, 2009).

Decoupling of impacts from consumption

Along with many developed economies, the UK has a strong negative mineral trade balance (Bide et al, 2013). Both primary and manufactured goods flow from producers elsewhere in the world with lower marginal costs. As set out above minerals in particular benefit from economies of scale and bulk logistics. In some jurisdictions, minerals extraction almost certainly benefits from lower environmental costs. As well as enjoying the economic benefits of this globalisation, it might also be true to say that by 'offshoring' their mineral production, the British have also moved their environmental impacts and obligations away from their own backyard.

Rising Demand And Renewed Resource Security Concerns

In the first few years of the 21st Century, the global economy boomed and the emerging economies of Asia and South America enjoyed very high economic growth rates. At the same time, old concerns about mineral resource security re-emerged in Europe and North America. These concerns focussed on both supply (physical and environmental limits, geopolitics, resource nationalism, production concentration and skill shortages) and demand (global population, emerging middle classes, step changes in technology). Despite the current recession, fears remain in the West as high commodity prices threaten recovery. As a consequence, EU and UK policy makers have begun to recognise the importance of material security (European Commission, 2010, DEFRA, 2012), although emphasis so far has been on resource efficiency and recycling. The impact and importance of primary supply has been a lesser consideration.

Physical scarcity

The most fundamental question related to security of supply is that of physical availability of minerals and metals from the Earth. Recently, a number of commentators (such as Ragnarsdóttir, 2008) have restated views first expressed in the early 19th century by Thomas Malthus (Malthus, 1798) that mankind is rapidly approaching the physical limits of a number of key metal and mineral resources.

The reality is that despite increasing metal production over the past 50 years, reserve levels have remained largely unchanged. Concerns regarding physical exhaustion of metals may be based on an over-simplistic view of the relationship between reserves and consumption (i.e. number of years supply remaining equals reserves divided by annual consumption). Metals of which we know the precise location, tonnage and which we can extract economically with existing technology - known as 'reserves' - are tiny in comparison to the total amount. Consumption and reserves change continually in response to scientific advances and market forces (Bloodworth and Gunn, 2012).

Resource nationalism and geopolitics

Global resource of minerals and metals are unevenly distributed and demand does not always coincide with supply. As a consequence, geopolitics and resource nationalism present a pressing current and future threat to the supply of some commodities. The 'haves' will try to maximize economic benefits and, sometimes, attempt to exert political influence over the 'have nots'. Relentless growth in demand resulting from burgeoning global population and the rapid expansion of large emerging economies such Brazil, Russia, India and China (the so- called 'BRIC' countries) has seen significant, real global price increases for most metals in the last decade (Figure 3). This pattern looks set to continue and it looks likely that most metal exporting countries will seek a larger share of the wealth generated by extractive industries. In most jurisdictions, this will be through taxation and royalties, but in a few countries, extractive operations may be nationalised.

The likelihood is that international tensions over resources will increase over the next few years (Ministry of Defence, 2010). The scramble for resources between western mining companies and enterprises (sometimes with direct state backing) based in emerging economies looks set to continue in Africa and elsewhere.

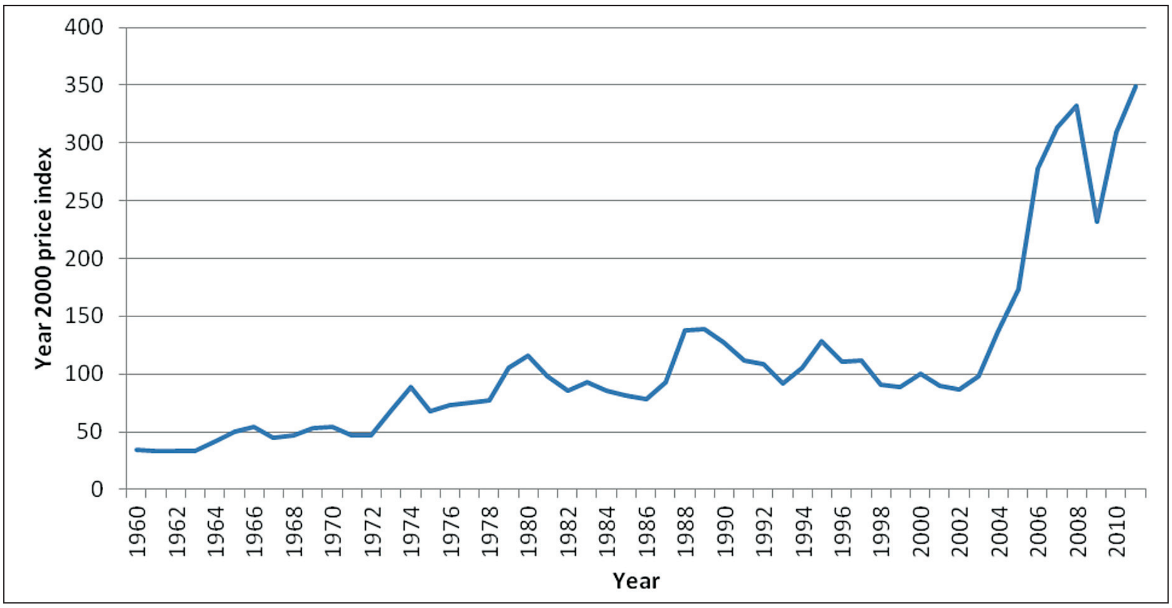

Figure 3. *Changes in the real global price of all common minerals and metals indexed at prices in 2000 (Data from UN Conference on Trade and Development).*

Technological development and uptake

Shortage of key metals or minerals can occur if the speed of technological development and/ or the speed of technology uptake outpaces supply. For example, the current drive to develop and introduce low carbon technologies has put pressure on supply of some metals. Renewable and low carbon energy generation technologies (such as wind turbines, nuclear and solar photovoltaic) generally rely on a number of so-called 'critical metals' for their manufacture as do technologies for low emission vehicles and for energy storage. Although uptake of all the environmental and energy technologies currently under development seems unlikely, large-scale adoption of some is inevitable. As such, demand for certain critical metals are set to grow rapidly from what is currently a low base. European and US studies (such as Moss et al, 2011) suggest that the rare earths cerium, dysprosium, terbium, europium, neodymium and yttrium are particularly critical for 'clean' energy technologies, as are a range of other metals including indium, tellurium, gallium, cadmium, niobium and selenium. Meeting this demand requires suitable mineral deposits to be found and developed into mines, which in turn requires adequate finance, as well as technical knowledge. The time required to bring these factors together imparts considerable inertia into the system and can lead to short-term supply shortages.

The Role Of Minerals In A Rebalanced British Economy

The UK is the World's 9th largest manufacturer (Mellows-Facer and Maer, 2012) and this sector is experiencing growth after decades of decline relative to other parts of the economy. British manufacturing is particularly strong in aerospace, defence and automotive sectors where long-term access to secure and stable supply of raw materials is a key factor. This supply can be compromised by lean 'just in time' supply chains which may heighten vulnerability to supply disruption. These industries are becoming increasingly concerned about the impact, which factors such as supply concentration and disruption, price volatility and long term availability might have on their supply chain (Buijs and Sievers, 2012). The UK Parliament House of Commons Science and Technology Committee inquiry into 'Strategically Important Metals' in 2011 (HCSTC, 2011) identified many of these vulnerabilities and set out some possible mitigation strategies including development of a stronger indigenous extractive sector. The UK Government's response to this inquiry was published in 2012 as the 'Resource Security Action Plan' (DEFRA, 2012). Whilst this document recognises the importance of mineral raw materials in sustaining the UK economy, it could be said that it overstates the potential of recycled materials in meeting rapidly growing demand for critical metals.

In its National Infrastructure Plan published in 2011, the UK Government aspires to Victorian levels of progress in building transport infrastructure (HM Treasury, 2011). Major road, rail, energy and coastal defence projects are required to bring UK infrastructure up to 21st Century standards and to underpin economic growth, quality of life and environmental objectives. Along with the wider economy, these projects will consume mineral raw materials including large quantities of construction aggregates. Issues related to port and onward transport capacity mean that any future substantial substitution of home-produced material by aggregates imported from outside the UK landmass and its adjacent continental shelf looks very unlikely (Brown et al, 2011). Aggregate supply will therefore be largely dependent on domestic resources of primary and secondary or recycled materials. Both primary and secondary resources are increasingly constrained by issues related to access and availability (Mankelow et al, 2008) and, given long lead times associated with obtaining a licence to operate, planning needs to begin for the next generation of large hard rock extraction sites (Hicks, 2008).

A New Era For Domestic Minerals Extraction?

Recent resource security concerns and commodity price rises discussed above have triggered a modest revival in interest in new mineral developments in the UK (Economist, 2011). For the first time since the mid-20th Century, new metal mines are opening in Scotland (Connonish gold) and Devon (Hemerdon, tungsten). Other companies are actively exploring for various metals in south west England. Development of major new potash resource in Yorkshire is currently under consideration by permitting authorities. The development of a major deep coking coal mine in south Wales is subject to a feasibility study and, controversially, exploration for shale gas looks likely to extend beyond the Fylde peninsular in Lancashire to other parts of the UK.

As in the past, technological innovation and development is important in both the identification of new domestic mineral resources and in their subsequent development. Hydraulic fracturing and other technical innovations related to efficient in situ gas recovery from shale and coal have opened the possibility to develop a major new indigenous energy source, although how much of that potential is realised depends on a host of complex environmental and societal factors related to access (Royal Society, 2012). Less controversially, advances in extractive hydrometallurgy may open up the possibility of relatively low-impact, low-carbon, multi-metal recovery from existing mine 'waste' arisings (such as those from kaolin extraction in south west England) or from legacy tips and mines in the old metal-mining terranes of the west and north of the UK.

Aside from the economic value of indigenous minerals and their contribution to the construction and manufacturing sectors, there is a growing recognition of the value of non-market ecosystem service provision by the domestic extractive sector (Davies, 2006). The minerals sector now routinely reports progress toward biodiversity targets for site restoration (Mineral Products Association, 2012) and this proactive approach to habitat restoration and creation makes a significant contribution to ecosystem service provision in lowland Britain (Bloodworth et al, 2009).

CONCLUSIONS

Global population growth and lifestyle changes in emerging economies are increasing demand for mineral commodities and energy. As a result, prices are rising and fears about supply security are growing in the industrialised economies. These concerns are a major factor in the renewed interest in UK mineral developments, although this must be set against equally strong views relating to protection of our environment. Local, secure sources of supply of mineral raw materials and easy access to regional European and global trade routes remain enduring and appealing factors for domestic production. These islands have been trading in minerals for 5000 years, and there never was and never will be a self-sufficient 'Fortress Britain'. However, our 'extractive history' teaches us that new technologies and valuations will continue to present us with new opportunities, as well as some sustainable and neighbourly solutions to mining on a small, crowded island.

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